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Surfacing of Dead Fish Following Application of Rotenone[1]

Despite the precautions advocated by some in estimating fish populations by poisoning with rotenone (Carlander and Lewis, 1948; Krumholz, 1950; Miller, 1950; Moorman and Ruhr, 1951; Carter, 1958; Lambou and Stern, 1958), Lambou and Stern (1958) urged additional investigation of the various conditions that affect the completeness of fish recovery after rotenone treatment. The literature indicates inter- and intraspecific variation in the percentage of fish that surface following death after rotenone treatment (Ball, 1948; Carlander and Lewis, 1948; Krumholz, 1950; Miller, 1950; Jenkins, 1957; Lambou and Stern, 1958; Rupp and DeRoche, 1965; Henley, 1967). If there is no relation between the quantity of dead fish observed at the surface and the standing crop, then the practice of using apparent kills to compare the standing crops of various waters is meaningless. If a constant relation can be demonstrated, however, then such a practice can be encouraged.

This study examined the rate and extent of surfacing[2] of rotenone killed fish in the laboratory and in the field, with special attention given to the influence of environmental factors on surfacing (Parker, 1967). After prelim-

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[2] The word surfacing throughout this paper refers only to dead fish.

TABLE 1.—*A summary of the effect of water temperature and depth on the rate of surfacing of centrarchids poisoned with rotenone*

Test	Number of fish	Size range	Temperature average (F)	Temperature range (F)	Depth (ft)	Time to surface (days)
8–33	208	2.6– 5.5	80.0	78.7–81.5	3–10	0.5–2
43	15	1.0– 4.0	74.5	74.0–75.0	1	0.5–1
1–7	585	1.6– 6.8	72.0	71.0–72.5	1.7	0.5–3
44	15	1.0– 4.0	62.5	62.0–63.0	1	1–2
34	154	1.5–10.0	63.0	61.0–67.0	10	2–4
35	11	5.0– 7.0	59.0	57.0–61.0	4–6.5	3–6
36–37	36	4.0–10.0	50.0	42.0–58.0	7–15	32+[1]
47	15	1.0– 4.0	40.0	39.0–40.0	1	20–41+[2,3]
45	14	1.0 –4.0		50.0–79.0	1	3–7[3,4]
46	15	1.0– 4.0		35.0–67.0	1	7–33+[3,4,5]

[1] Test was terminated as fish had rotted and would not have surfaced.
[2] On day 42 this aquarium was removed from the constant temperature chamber and allowed to reach room temperature (70 F).
[3] All adults surfaced but many young did not.
[4] As the temperature gradually rose, the bluegills surfaced.
[5] On day 31 this aquarium was allowed to reach room temperature (74 F).

inary work in the laboratory to establish test procedures, the consistency with which dead fish surface was studied under constant conditions by repeatedly poisoning various combinations of fish of a uniform size. A second series of controlled tests considered the effect of depth on surfacing. Field experiments were then conducted to substantiate the conclusions drawn from the above studies in four ponds renovated by the State of Ohio. Finally, the effect of temperature was investigated in the laboratory to clarify the field results. In all tests, physical and chemical characteristics of the water were recorded prior to poisoning. The principal species used in controlled tests were bluegill, *Lepomis macrochirus*; green sunfish, *Lepomis cyanellus*; golden shiner, *Notemigonus crysoleucas*; goldfish, *Carassius auratus*; and brown bullhead, *Ictalurus nebulosus*. The most common species observed in field studies were bluegill, green sunfish, orangespotted sunfish, *Lepomis humilis*; white crappie, *Pomoxis annularis*; quillback, *Carpiodes cyprinus*, and black bullhead, *Ictalurus melas*.

Practically all rotenoned fish (1,105 of 1,119, 1–9.1 inches total length) in the 43 controlled tests surfaced after death. Water temperature and depth (10 feet or less) affected the rate of surfacing, which was slower in colder or deeper water (Table 1). The following factors, within the limits indicated, do not appear to affect the rate of surfacing: dissolved oxygen (3.8 to 13.8 ppm), total alkalinity (40.0 to 140.0 ppm as $CaCo_3$), hydrogen ion concentration (7.7 to 8.5), total hardness (110.0 to 222.3 ppm), transparency (clear to 8 inches), and rotenone concentration (0.5 to 6.3 ppm of 5% rotenone). The results of the first two field studies in water temperatures above 56 F were similar to the above. However, in the last two field studies most of the dead fish (bluegills and green sunfish) remained on the bottom and eventually decomposed. Water temperatures were 42 to 58 F and depths ranged from 2 to 15 feet. Further tests under controlled conditions showed that poisoned bluegills surface at a considerably slower rate at lower temperatures and that in temperatures below 62 F and at 1 foot depths some remain on the bottom and decompose. Because total hardness in these ponds is much higher than in the other impoundments studied (553 to 970 ppm higher), it could have also affected surfacing and should be further investigated. Results of one field study indicate that in cold water dead bullheads surface at a slower rate than centrarchids, at least 2 days later in temperatures of 57 to 61 F. Other tests indicated that dead minnows surface considerably faster than centrarchids, 11 to 26 hours faster in 72 F water to 20 days faster in 40 F water.

Information obtained from the controlled tests, combined with the results of the four field studies, indicates that in water temperatures above 60 F, in depths to at least 10 feet, and in waters lacking abundant rooted aquatic plants, practically all rotenone-killed fish can be expected to surface within 1 week. Thus, accurate determinations of standing crops can be made if all the fish are killed, and if dead

fish are removed daily to minimize losses from scavenging and decomposition.

More investigation of how temperature and depth affect fish surfacing after death is certainly needed, particularly with other species and in situations where depths exceed 10 feet. Most studies claiming that varying percentages of fish among and within species come to the surface after death following rotenone treatment were conducted in waters deeper than 10 feet and/or were of short duration, usually only 3 days.

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